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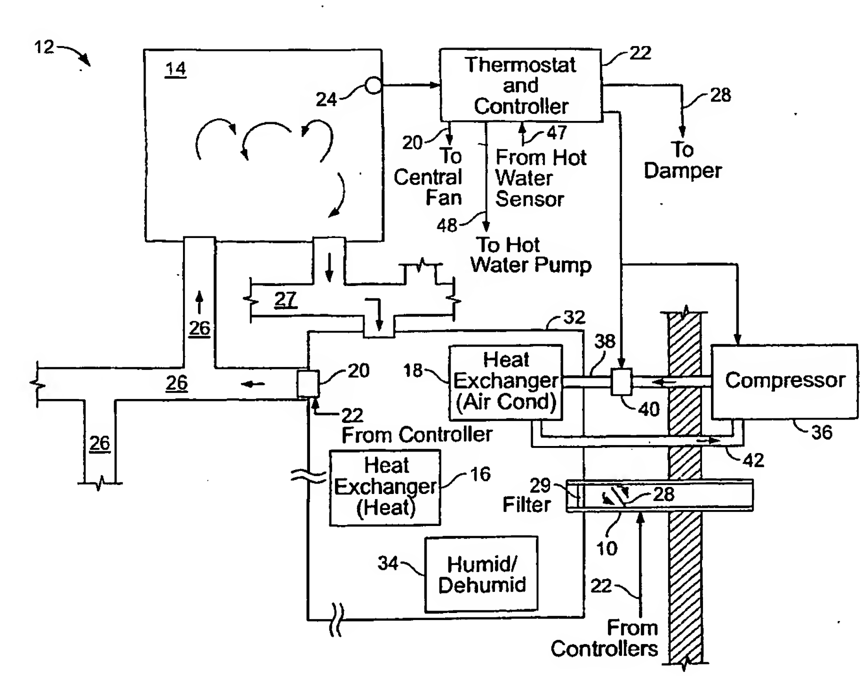
(54) Title: DAMPER CONTROL IN SPACE HEATING AND COOLING



(57) Abstract: An amount of time that air has been delivered from an air handler to a space is tracked, and based on the tracked amount of time, at least one turn-on time or one turn-off time of the delivery of air from the air handler to the space is controlled.

WO 2005/100870 A2

DAMPER CONTROL IN SPACE HEATING AND COOLING

BACKGROUND

This description relates to damper control in space heating and cooling.

During the 1990s, the United States Department of Energy sponsored research on how to save energy in heating and cooling houses and other buildings. As shown in figure 1, one recommendation that has begun to be widely adopted is to super-insulate buildings, seal them tightly against air infiltration, and use a vent 10 from the outside world 12 to let in fresh air. The fresh air is needed to clear odors and humidity from the tightly sealed spaces 14 that are occupied within the buildings. The energy savings produced by such a system are so large that it is expected that, in the future, most new buildings will be super-insulated and tightly sealed.

As is typical of forced air heating or cooling systems, the heater or cooler 16, 18 (and a central fan 20) is turned on and off in response to a thermostat and controller 22 based on a comparison of a set point temperature and a current air temperature measured at a temperature sensor 24. The central fan 20 forces air from the heater or cooler through ducts 26 into the occupied spaces 14. Stale air is withdrawn from the spaces through return ducts 27 and returned to the intake side of the air handler. While the heater or cooler is running, the stale returned air is supplemented with fresh air that is drawn into the building through the vent 10. A damper 28 inside vent 10 is set in a fixed position to permit no more than a suitable amount of fresh air to be drawn in while the heater or cooler is running.

Even during intervals when the heater or cooler is not running, fresh air continues to be needed, and for this purpose, the central fan may be run from time to time during those intervals.

Heating and cooling systems are generally sized so that they run almost full-time during the coldest or warmest months. When a system that draws in fresh air from the outside world runs all the time, more air is drawn in than is needed for air exchange purposes, and energy is wasted in heating or cooling it. By motorizing the damper 28, it is possible to open and close the damper in cycles to reduce the amount of fresh air drawn into the building. In some

of replacement air to an air handler to be achieved during periods when a vent that controls the delivery of replacement air is open.

Implementations of the invention may include one or more of the following features. The information about an intended flow rate of replacement air includes a value indicating an average volume of air per time period. The value is specified by a user. The information about an intended amount of time is specified by a user. The calculation includes dividing the intended flow rate by the amount of time. The calculation is also based on information about a duration of a duty cycle of a fan that delivers the replacement air to the space.

In general, in another aspect, the invention features enabling a user of a controller associated with an air handler to enter a value of an amount of replacement air to be delivered to a space. In some implementations, the amount of the replacement air is expressed as an average volume per time.

In general, in another aspect, the invention features enabling a user of a controller associated with an air handler to enter a value of a minimum amount of time that a fan of the air handler is to run. In some implementations, the user is enabled to enter a value of a duty cycle of the fan.

In general, in another aspect, the invention features enabling a user of a controller associated with an air handler to enter a value of an amount of replacement air to be delivered to a space, a value of a minimum amount of time that a fan of the air handler is to run, and a value of a duty cycle of the fan.

In general, in another aspect, the invention features enabling a user of a controller associated with an air handler to enter an indication of a temporary change in an amount of replacement air to be delivered from an air handler to a space.

Implementations of the invention may include one or more of the following features. The user is enabled to enter an indication of the duration of the temporary change. The temporary change includes an increase associated with an increase in anticipated occupancy of the space. The temporary change includes a decrease associated with a decrease in anticipated occupancy of the space.

In general, in another aspect, the invention features an apparatus including, as an assembly, a controllable damper to regulate flow of air through an air flow passage between an exterior of a building and an air handler, a sensor to sense air flow through the passage, and terminals to connect the sensor and the controllable damper in a control circuit.

Implementations of the invention may include one or more of the following features. The sensor includes a contactless sensor. The sensor includes magnetic elements. The sensor includes a fan in the passage to rotate in response to air flowing through the passage. The rotation of the fan is sensed as an indicator of the volume per unit time of air flowing through the passage. The fan includes blades, at least one of the blades bears a magnet, and the sensor senses motion of the magnet. The damper is controllable to be open or closed. The damper is also controllable to be open to a selected position among at least two different open positions. The damper is controllable to be open to a selected position with a range of positions. The damper includes a rotating flap driven by an electric motor. The fan is free-wheeling. The control circuit controls opening and closing of the damper in response to sensed air flow through the passage. A filter filters air flowing through the passage. A housing defines at least a portion of the air flow passage and includes ends to mount the housing between an exterior of a building and an air handler. The housing also supports the damper, the sensor, and the terminals. The housing also supports a filter. The filter is mounted on a second structure that mates with the housing. The housing also supports at least a portion of the control circuit. The controller includes a circuit that receives signals from the sensor and sends signals to the controllable damper. The control circuit includes a terminal to connect to a thermostat. The control circuit includes an input to receive an indication from a user of how much air is to be permitted to flow through the passage. The control circuit includes logic to control the damper to allow a predetermined volume per unit time to flow in the passage.

In general, in another aspect, the invention features an apparatus including a controllable damper to regulate flow of air through an air flow passage between an exterior of a building and an air handler, a sensor to sense air flow through the passage, a control circuit to receive signals from the sensor and to send signals to cause the controllable damper to allow a predetermined volume per unit time to flow in the passage, and a housing that supports the

sensing unit 52 includes an air flow sensor (hidden in figure 2) that produces a stream of signals from which the volume of air that passes along the air path per unit of time (e.g., 20 cubic feet per minute, CFM) may be derived.

The derivation of the CFM can be done, in one example, by a processor in a local electronic circuit 56 (which we sometimes call an airflow controller) that is mounted on the sensing unit 52 or, in another example, can be sent by a cable 58 to a thermostat and controller 60 (which we sometimes call simply a controller or a main controller) mounted on a wall 62 of a space of a building.

The main controller 60 contains a thermostat circuit that compares data indicative of the temperature in the space with a desired set point temperature. In some implementations, the controller itself may not contain a temperature sensor but may be connected as a controller to an existing thermostat and in that role monitors the existing thermostat. The controller 60 sends control signals on a cable 66 to a set of drivers 68 on the air handler to control heating and cooling to drive the temperature in the space to reach the set point and to control central fan operation during heating and cooling and at other times. The controller 60 may also receive data on a cable 70 from an outside sensor 72 that senses one or both of the relative humidity and temperature of the outside air and may use the data as part of an algorithm that determines when to call for heating or cooling.

(For example, if the controller determines that the outside temperature is cooler than the inside temperature at a time when cooling is being requested, the controller could open the damper fully and turn on the central fan for a period to attempt to cool the space with outside air without using the cooling feature of the air handler. The converse determination could be made for heating when the outside temperature is warmer than the inside temperature.

If the outside relative humidity is high during a call for cooling, the controller could allow the space to be cooled a small amount lower than the set point to allow long cooling runs to dry out the inside air. Short cycling the air handler for cooling tends not to remove much water from the air, which can occur if a system is over-sized. In another use, if the outside air temperature is close to the inside air temperature, which could result in relatively little fresh

As shown in figures 3, 4, and 5, the damper 50 includes a molded cylindrical body 94 and a molded flat round vane 95. Approximately halfway along the inner wall of the body 94 is a circular rim 96 that projects into the space within the cylindrical body to define a closed position at which the damper is stopped as it is rotated to the closed position.

On the outer wall of the body 94, a flat surface 98 is defined to support an electric stepper motor and gear assembly 100 used to drive the damper to selected positions based on signals sent from the controller.

At two diametrically opposite positions around the rim 96 are two holes 90, 92. The vane 95 (which is not shown in figures 3 and 4) has two slightly offset (along an axis normal to the vane) semicircular plates 97, 99, joined at a central tube 91. The damper is held in place in the body 94 by two pins 93, 97 (figure 3), one that projects from hole 90 into one end of the central tube. One end of the other pin is connected to a shaft of the motor and gear assembly 100. The other end of that pin projects into the other end of the central tube 91 and is keyed into that hole so that rotation of the motor causes rotation of the damper.

The circular end 102 of the body of the damper 50 that connects to the sensor unit has projecting fingers 106, 108 that mate with and lock into corresponding holes 109, 111 (figure 6) in a body of the sensor unit. The other end 103 of the body of the damper 50, which connects to the flange 82, has two holes 110, 112 to receive projecting fingers similar to the fingers 106, 108.

Referring to figure 7, the flange 82 has a round end 120 having an inside diameter that is slightly larger than the outside diameter of the end of the damper with which it mates. Two fingers 122, 123 project into the space defined by the round end 120 and mate with the holes 110, 112 of the damper. All of the fingers 106, 108, 122, 123 have tapered leading edges to permit then to be easily forced into the mating holes and have blunt trailing edges to make them hard to remove from the mating holes except by inserting a tool through the holes and against the fingers to force them out of the holes.

The flange 82 includes a square cross-section tapered wall 126 that tapers from the round end 120 to a square cross-section to the opposite square end 128 of the flange. The square end is

damper is connected to a source of power and the signal lines among the airflow controller and the damper are connected to the main controller. A filter is inserted into the pocket at the interface between the air handler and the flange.

Once the assembly 180 has been installed, when the damper is open and air is drawn into the air handler from the outside, the air moves through the sensor causing the fan to rotate. The fan rotates more rapidly with higher velocity of air motion. The rotation of the fan is indicative of the air flow volume per unit time. As the fan rotates, the airflow controller detects when each of the magnets on the blades passes the location of a magnetic detector that is part of the airflow controller. The airflow controller then determines the RPM (which may be the instantaneous RPM in some examples, or an averaged RPM in other examples). Based on the RPM signals, the main controller converts the RPM signals to a flow rate in CFM, for example, by using a stored look-up table that associates flow rates with rotation rates as determined empirically.

The airflow controller circuitry 202 and the main controller circuitry 204 and their interconnections are shown in figure 10.

The main controller includes a microprocessor 204, a display 206 that is controlled by the microprocessor, and a keyboard 208 that enables a user to manage the operation of the main controller. In one implementation, the keypad provides eight keys (membrane switch keys 1 through 6, and up, down, and mode buttons), and the display has the configuration shown in the figure. The microprocessor includes control outputs 209 for the fan driver 210, the heat driver 212, a second heat driver 214, and a cooling driver 216. The outputs are carried on a cable 66 to the air handler where the drivers are located.

The main controller includes a thermistor 218 to detect the temperature within the space being heated or cooled. The main controller may also include a relative humidity sensor 220. Optionally, the microprocessor can also receive signals from an outside temperature sensor and an outside relative humidity sensor 72 that are mounted in a position exposed to the outside world. Data to be sent back and forth between the main controller and the airflow controller on the cable 58 is handled by a network interface 222 at the main controller end of

airflow control sends back the value of the fan RPM. When the main controller commands the slave to change the LED's state, the airflow controller replies with an acknowledgement.

Figures 11A, 11B, and 11C show a front view with cover closed, a perspective view, and a front view with cover open of the external housing of the main controller. In addition to controlling the fan on periods and the damper open periods, the controller serves as a conventional programmable thermostat. For this purpose it provides keys to program a weekday set point schedule and a weekend set point schedule, and keys to set the day and time. A fifth key controls the set point and a hold key sets the hold function. The two buttons that have up and down arrows are used to increase or decrease a value and the square button serves a similar role to an enter button on a keyboard.

The mode and up and down buttons are used to set Af, Fp, and Fm values (described later). The controller includes a main housing and a base that is attached to the wall. The main housing snaps onto the base. By holding the up button in while snapping the housing to the base, the microprocessor is alerted to enter setup mode. Once in setup mode the display indicates the value that is being set. Pressing the mode button cycles through the three variables that are to be set. When a given variable is in set mode, the up and down arrows control the value of the setting. Other arrangements could be used to invoke the setup mode, for example, pressing a combination of the membrane switches at one time. In some implementations, a separate device may be provided to read out data from the controller and the device may also be able to lock and unlock the settings or to re-program the settings and then lock the settings so that the user is precluded from changing them.

The hold button controls both the hold options and the high occupancy options. The hold options could include setting a number of days for holding, or setting to hold indefinitely. The high occupancy option would hold the setting for a specified number of hours.

To operate the system, the user may use the keypad and the display of the controller to enter several values to be used by the control algorithm . One value is an average desired fresh air flow rate into the space being heated or cooled, called Af and expressed in cubic feet per minute. The user can determine what this value should be by using simple recommendations of another party or by doing a calculation on a website based on the characteristics of the

user presses the high-occupancy button, the controller prompts for a number of hours to maintain the high occupancy mode. During the period when the mode is maintained, the temperature is held at the current set point, and setback scheduling may be disabled. The fresh air flow rate Af is increased to a pre-set maximum flow rate, for example 90 CFM. The fan minimum run time, Fr, is increased to a pre-set run time, for example, 10 minutes. During high occupancy mode, if the set point temperature cannot be maintained, then the fresh air flow rate Af will be decreased until the set point temperature is reached. Reducing the fresh air flow rate in this way will enable the heater or cooler to adjust the temperature to the set point.

As shown in figure 12, in some control systems a user can indicate the percentage of time (for example, 33%) that he would like the central fan of the air handler to run--whether or not the thermostat is calling for heating or cooling--in order to keep air circulating in the space. Such systems track off time as a control technique. Note that the fan is always on when the thermostat is calling for heating or cooling. During periods when the thermostat is not calling for heating or cooling, the system monitors the amount of off time. If the amount of off time exceeds the desired percentage, then the fan is turned on.

For example, as shown in the figure, the user may specify that the central fan should run 33% of each 30-minute period. Suppose that the thermostat makes no call for heating or cooling at any time during the 30-minute period. Time line 402, in the upper half of the figure, shows the on and off periods of the fan during. For the first 30 minutes, the thermostat is not calling for heating or cooling and the central fan is on 404 for the first 10 minutes, then off 406 for 20 minutes in order to meet the desired percentage of on time. The same pattern is repeated in the second 30 minutes. In this example, the desired proportion of fan on time, 33%, is accurately achieved.

By contrast, in the time line 408, shown in the bottom half of figure 12, the desired proportion of fan on time is not met. In this example, the thermostat calls for cooling for 4 minutes 410, followed by an interval 412 of 16 minutes of no cooling, and then the pattern repeats. During the first 4 minute cooling period, the fan runs. When the cooling ends, the fan is turned off. If no cooling were then required for more than 20 minutes, the fan would be turned on by the algorithm, which watches the amount of off time to assure that the fan is

Thus the controller is able to achieve the desired fan on time with no excess (which wastes power and may take in too much air) and no shortfall (which may leave the air in the space stale).

Figures 12 and 13 are focused on the timing of fan on and off periods. We now consider how the damper may be controlled to assure that a desired amount of fresh air is provided to the space. Figure 14 illustrates that some known systems for controlling the open or closed state of the damper (vent) do not accurately meet the desired proportion of open time. As shown in the example, in such systems the user can specify the proportion of time that the vent is open, ~~say, 33%, which corresponds to 10 minutes open and 20 minutes closed per half hour.~~

Suppose that, in the example, the thermostat is calling for heat for 10 minutes at the beginning of each successive 15-minute period. In the known system, the vent is open when and only when the fan is operating. Because the operation of the fan to serve the heating need is more than enough tot meet the desired 10 minute per half hour vent open time, the time line 450 represents the periods when heat is and is not being called for, and implicitly when the fan is running and not running and the damper is open and not open. In the example, the total fan on time and hence the total damper open time is 40 minutes during the hour, or 66% of the time, which is an error of 100% in the desired proportion of damper open time. Because the damper is open more time than is needed, energy will be wasted.

In a different control approach, illustrated in figure 15, the user specifically sets the fresh air rate Af at, say, 30 CFM, the minimum fan run time Fm at 10 minutes, and the duty cycle Fr at 30 minutes. The controller uses these settings to calculate a required flow rate of 90 CFM to be achieved for 10 minutes in every 30-minute period. The upper time line 452 in figure 15 shows, as did the time line in figure 14, the periods when the heat is and is not being called for. The lower time line 454 in figure 15 shows the periods when the damper is open and closed. In the initial 10-minute period 456, when the fan is running, the damper is opened enough to achieve a 90 CFM flow rate, as determined by the controller. In the next, 20-minute period 458, running to the end of the half-hour, the damper is closed because the controller has determined that the quota of damper open time for that half hour has been met. The periods are then repeated in the second half hour. Unlike the system shown in figure 14

needs to be provided to the space. Or even tighter building techniques could produce a need for higher than previously recommended fresh air replacement rates Conversely it could be yet a new building method where the home was tighter.

By monitoring the airflow and/or the damper position over time in a given system, it is also possible to determine when the filter needs to be cleaned or replaced. Decreases in the airflow rate will indicate blockage of airflow. When the airflow falls below a predetermined value, an indicator can tell a user that it is time for filter maintenance. The predetermined value may be set empirically for systems in general, or for each installed system in particular. Empirical analysis may not be required, because filter maintenance time may also be inferred from the profile of declining airflow. For example, the algorithm could watch for an abrupt change in airflow as an indicator that a filter situated upstream of the central fan is clogged. In that circumstance, the damper would be held open all the time and yet not be delivering the needed fresh air.

If the filter is on the downstream side of the central fan, as the filter clogs more air will be drawn from the outside, increasing air flow and drawing in more air than is appropriate to mix with the recirculated air. In the latter case, when the filter clogs, the pressure in the air handler drops and the flow from the outside world increases. The algorithm would detect these events and trigger an indicator that the filter should be replaced or cleaned.

When a new filter is installed, the algorithm could determine that fact automatically by watching for a prolonged abrupt decrease or increase in air flow that lasts at least, say, 10 minutes. The algorithm could then store the air flow rate for the new filter. When the air flow rate increases or decreases from the new filter rate by a change amount that is predetermined the filter maintenance alarm would be raised.

Before a filter is fully clogged and as it becomes slowly clogged from its new state, the algorithm will automatically accommodate the change in air flow. Thus the system will achieve both a longer effective filter life and simultaneously achieve a more constant and precise air flow rate.

Controlling of the duty cycle of the damper in the fully open and fully closed states may be a simple and economical way to achieve a desired average flow rate, and controlling of the duty cycle might be combined with controlling the amount of opening and closing of the damper to achieve a precise instantaneous air flow rate.

11. A medium bearing instructions to cause a machine to

track an amount of time that air has been delivered from an air handler to a space, and

based on the tracked amount of time, control at least one turn-on time or one turn-off time of the delivery of air from the air handler to the space.

12. Apparatus comprising

a controller to

track an amount of time that air has been delivered from an air handler to a space, and

based on the tracked amount of time, control at least one turn-on time or one turn-off time of the delivery of air from the air handler to the space.

13. A method comprising

based on information about an intended flow rate of replacement air to an air handler and an intended amount of time that air is to be delivered from the air handler to the space, performing a calculation to determine a flow rate of replacement air to an air handler to be achieved during periods when a vent that controls the delivery of replacement air is open.

14. The method of claim 13 in which the information about an intended flow rate of replacement air comprises a value indicating an average volume of air per time period.

15. The method of claim 13 in which the value is specified by a user.

16. The method of claim 13 in which the information about an intended amount of time is specified by a user.

17. The method of claim 13 in which the calculation includes dividing the intended flow rate by the amount of time.

18. The method of claim 13 in which the calculation is also based on information about a duration of a duty cycle of a fan that delivers the replacement air to the space.

26. The method of claim 25 also comprising enabling the user to enter a value of a duty cycle of the fan.

27. A medium bearing instructions to cause a machine to enable a user of a controller associated with an air handler to enter a value of a minimum amount of time that a fan of the air handler is to run.

28. Apparatus comprising

a controller to enable a user of a controller associated with an air handler to enter a value of a minimum amount of time that a fan of the air handler is to run.

29. A method comprising

enabling a user of a controller associated with an air handler to enter a value of an amount of replacement air to be delivered to a space, a value of a minimum amount of time that a fan of the air handler is to run, and a value of a duty cycle of the fan.

30. A method comprising

enabling a user of a controller associated with an air handler to enter an indication of a temporary change in an amount of replacement air to be delivered from an air handler to a space.

31. The method of claim 30 also including enabling the user to enter an indication of the duration of the temporary change.

32. The method of claim 30 in which the temporary change comprises an increase associated with an increase in anticipated occupancy of the space.

33. The method of claim 30 in which the temporary change comprises a decrease associated with a decrease in anticipated occupancy of the space.

34. A medium bearing instructions to cause a machine to enable a user of a controller associated with an air handler to enter an indication of a temporary change in an amount of replacement air to be delivered from an air handler to a space.

45. A medium bearing instructions to cause a machine to

sense flow of replacement air through a vent to an air handler,

open and close the vent to regulate delivery of replacement air to the air handler to achieve an intended rate of flow, and

based on the sensed flow, determine a clogging state of the filter.

46. Apparatus comprising

a controller to (a) sense flow of replacement air through a vent to an air handler, (b) open and close the vent to regulate delivery of replacement air to the air handler to achieve an intended rate of flow, and (c) based on the sensed flow, determine a clogging state of the filter.

47. A method comprising

issuing a vent signal to open a vent that regulates delivery of replacement air to an air handler, and

in connection with the issuing of the vent signal, issuing a fan signal to turn on a circulating fan of the air handler.

48. The method of claim 47 in which the fan signal turns on the fan independently of a thermostat that controls the air handler.

49. The method of claim 48 in which the fan is turned on using a relay.

50. A medium bearing instructions to cause a machine to

issue a vent signal to open a vent that regulates delivery of replacement air to an air handler, and

in connection with the issuing of the vent signal, issue a fan signal to turn on a circulating fan of the air handler.

59. Apparatus comprising

a controllable damper to regulate flow of air through an air flow passage between an exterior of a building and an air handler,

a sensor to sense air flow through the passage, and

terminals to connect the sensor and the controllable damper in a control circuit.

60. The apparatus of claim 59 in which the sensor comprises a contactless sensor.

61. The apparatus of claim 59 in which the sensor comprise magnetic elements.

62. The apparatus of claim 59 in which the sensor comprises a fan in the passage to rotate in response to air flowing through the passage.

63. The apparatus of claim 62 in which rotation of the fan is sensed as an indicator of the volume per unit time of air flowing through the passage.

64. The apparatus of claim 62 in which the fan comprises blades, at least one of the blades bears a magnet, and the sensor senses motion of the magnet.

65. The apparatus of claim 59 in which the damper is controllable to be open or closed.

66. The apparatus of claim 65 in which the damper is also controllable to be open to a selected position among at least two different open positions.

67. The apparatus of claim 59 in which the damper is controllable to be open to a selected position with a range of positions.

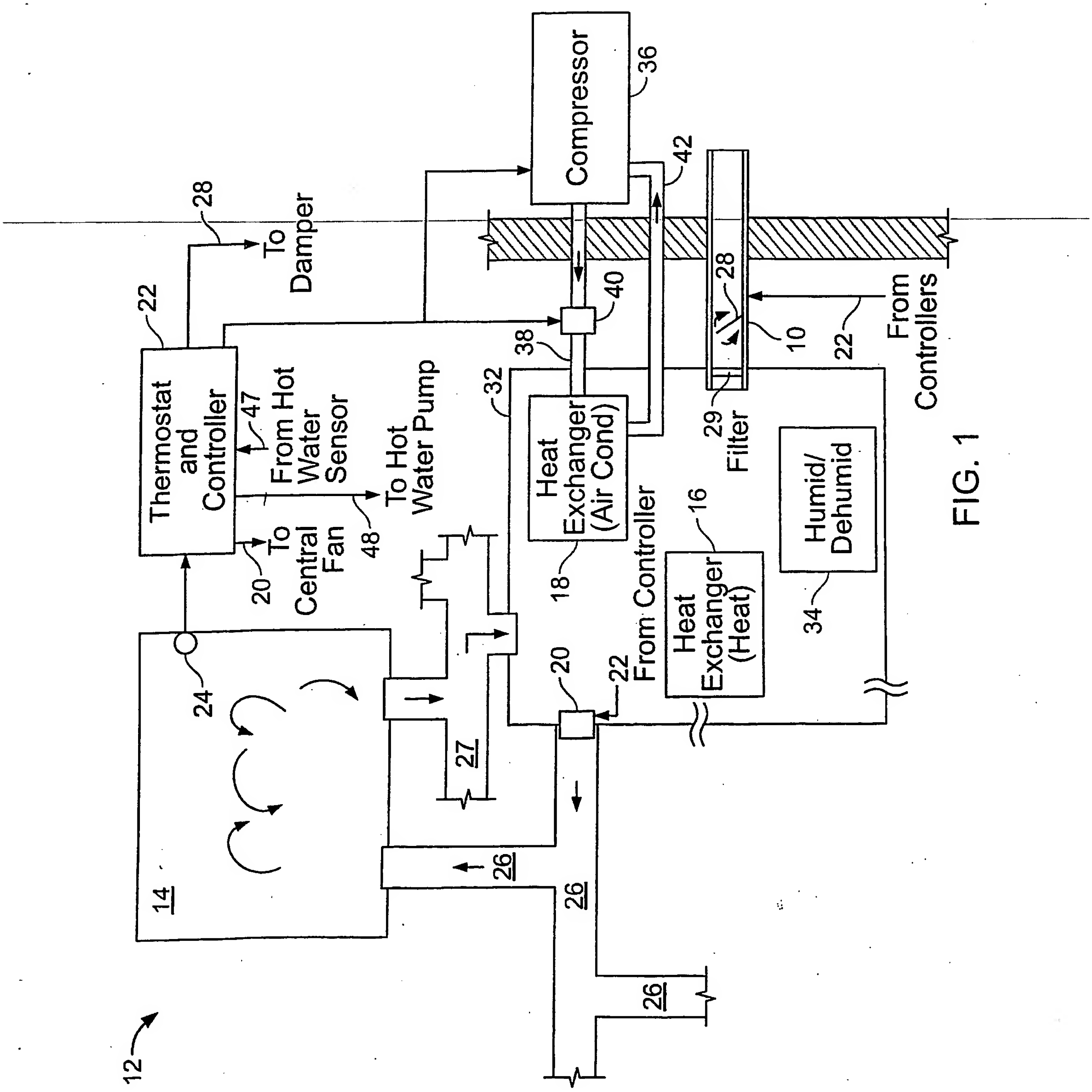
68. The apparatus of claim 59 in which the damper comprises a rotating flap driven by an electric motor.

69. The apparatus of claim 62 in which the fan is free-wheeling.

70. The apparatus of claim 59 in which the control circuit controls opening and closing of the damper in response to sensed air flow through the passage.

a control circuit to receive signals from the sensor and to send signals to cause the controllable damper to allow a predetermined volume per unit time to flow in the passage, and

a housing that supports the damper and the sensor and includes features to mount the housing between an exterior of a building and an air handler.



Compressor
36
42
28
To Damper
22
Thermostat and Controller
47
From Hot Water Sensor
To Hot Water Pump
48
To Central Fan
20
40
38
32
Heat Exchanger (Air Cond)
18
28
10
22
From Controllers
29
Filter
Humid/ Dehumid
34
From Controller
16
Heat Exchanger (Heat)
20
22
24
27
26
26
26
14
12

FIG. 1

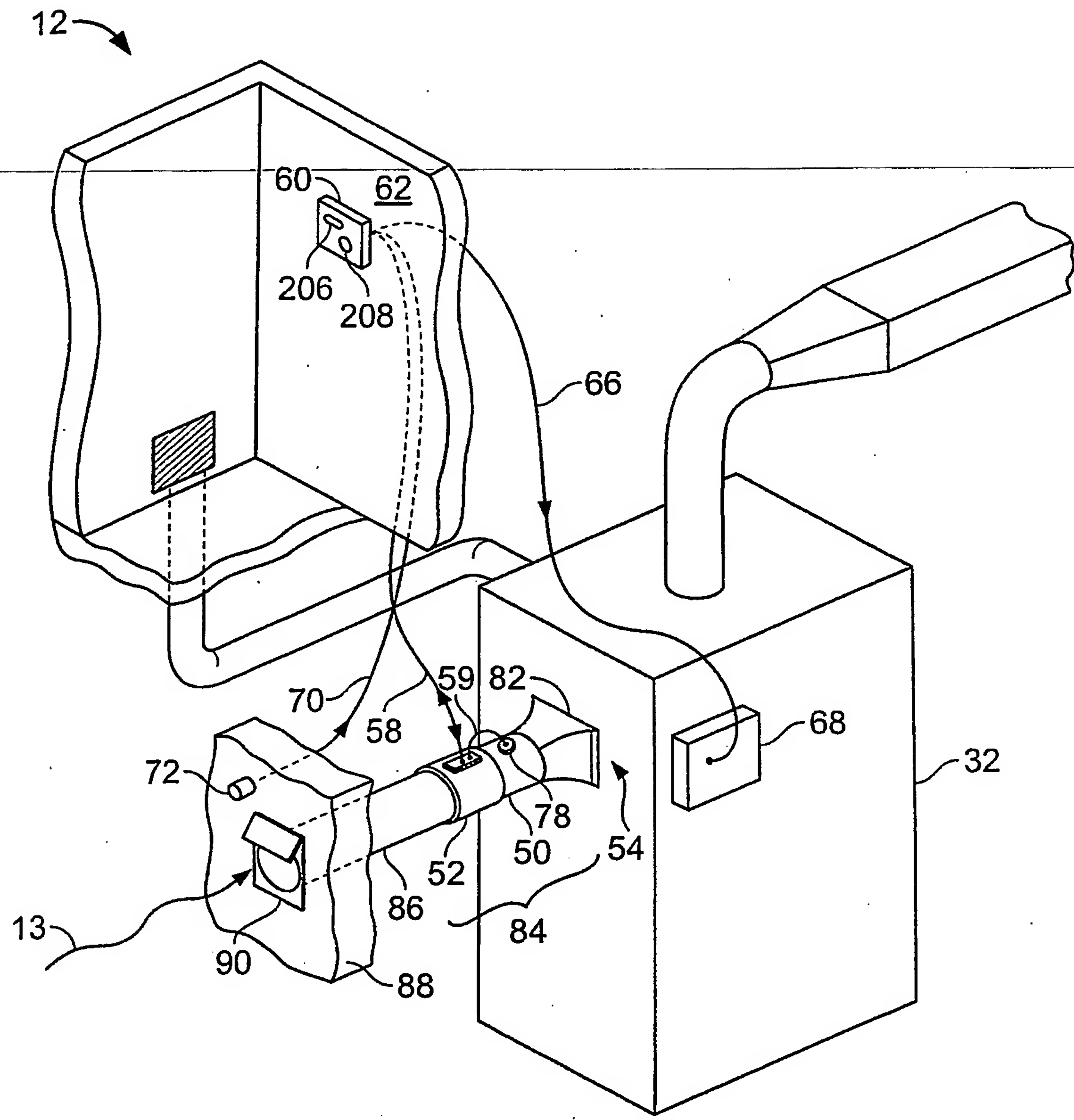


FIG. 2

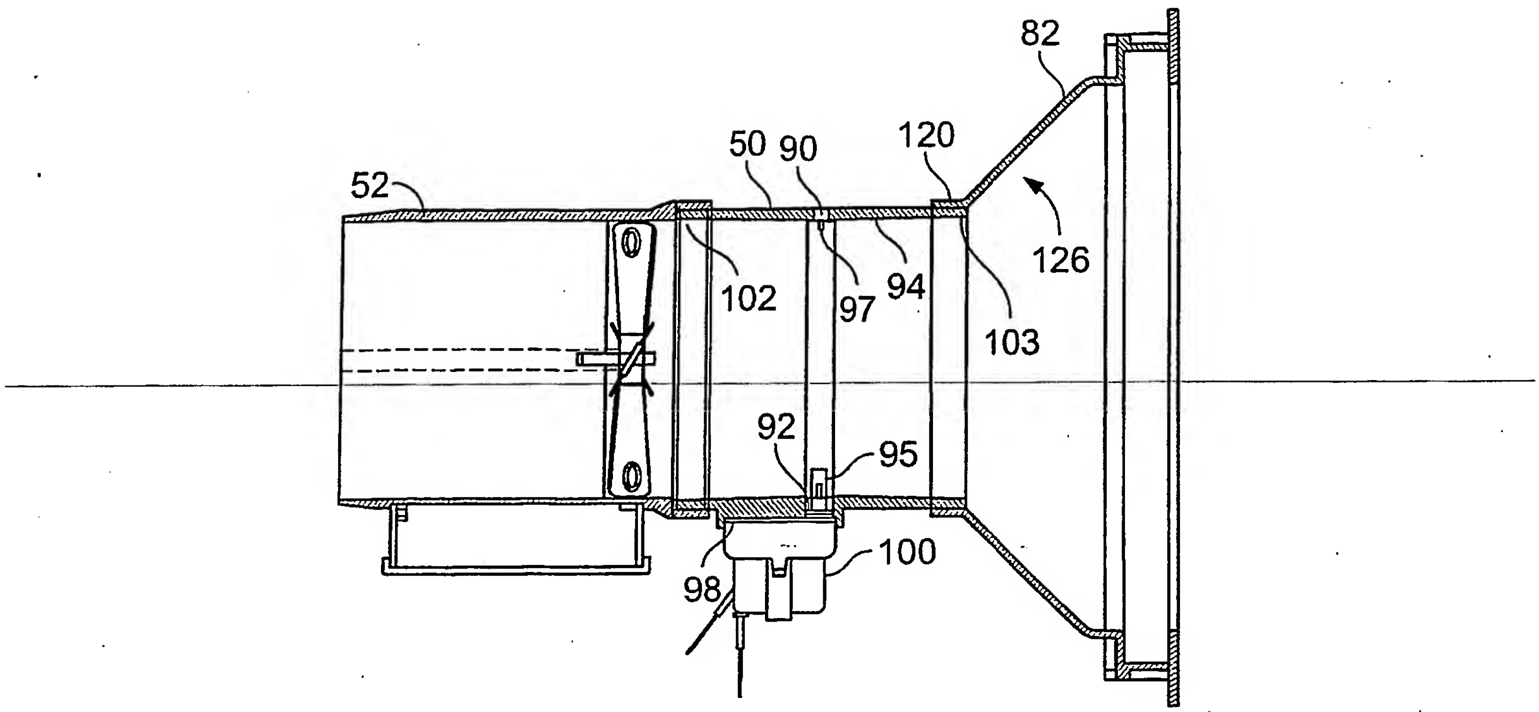

82
50 90
120
52
102
97
94
126
103
92
95
98
100

FIG. 3

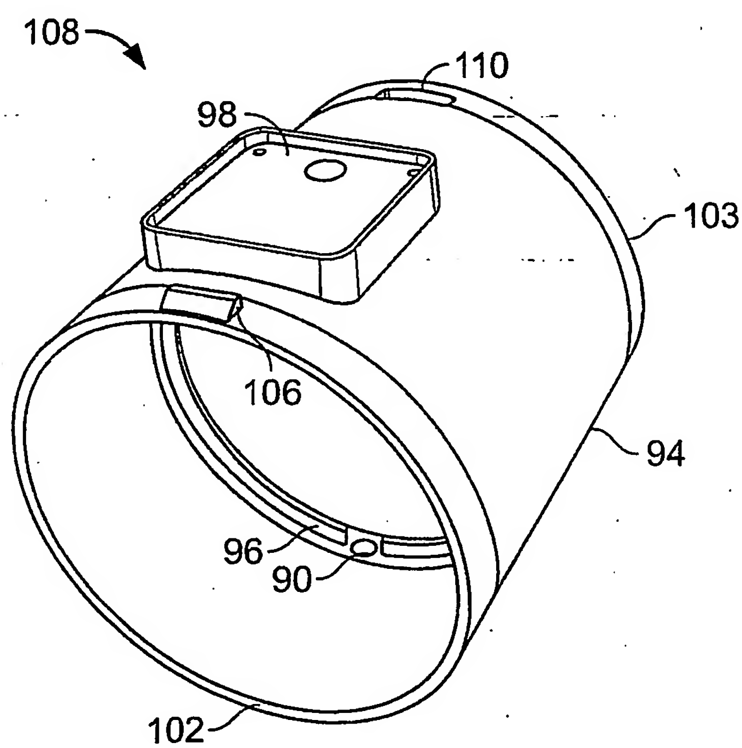

108
110
98
103
106
94
96
90
102

FIG. 4

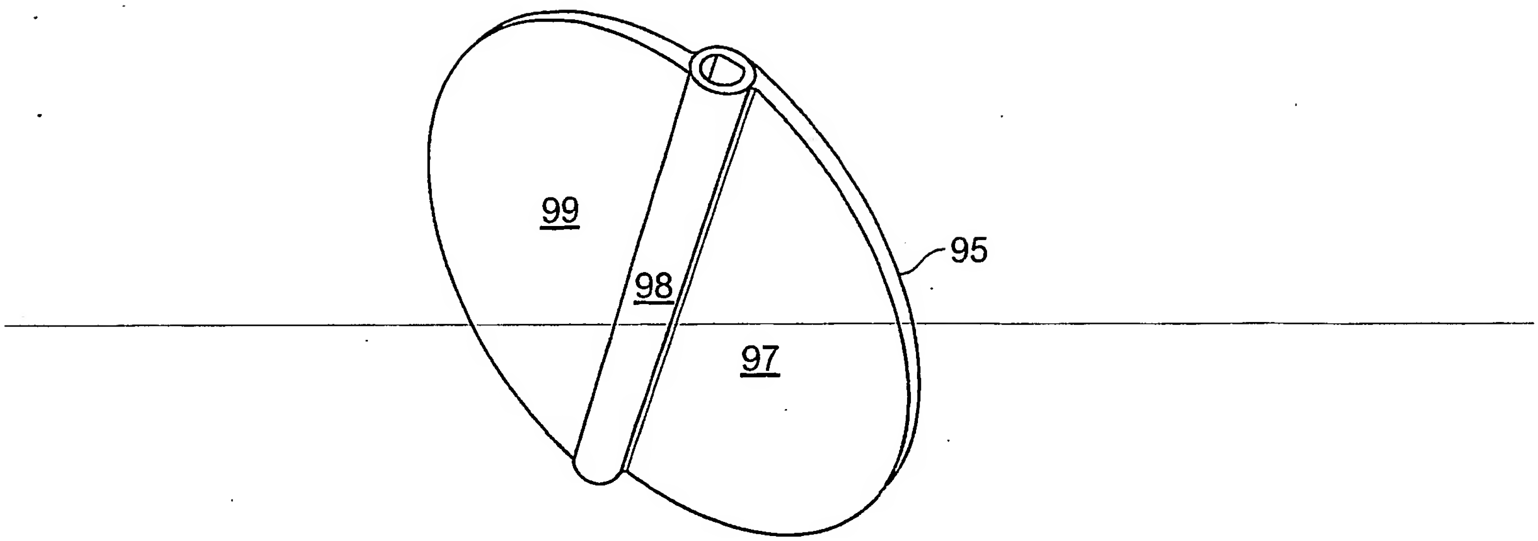


FIG. 5

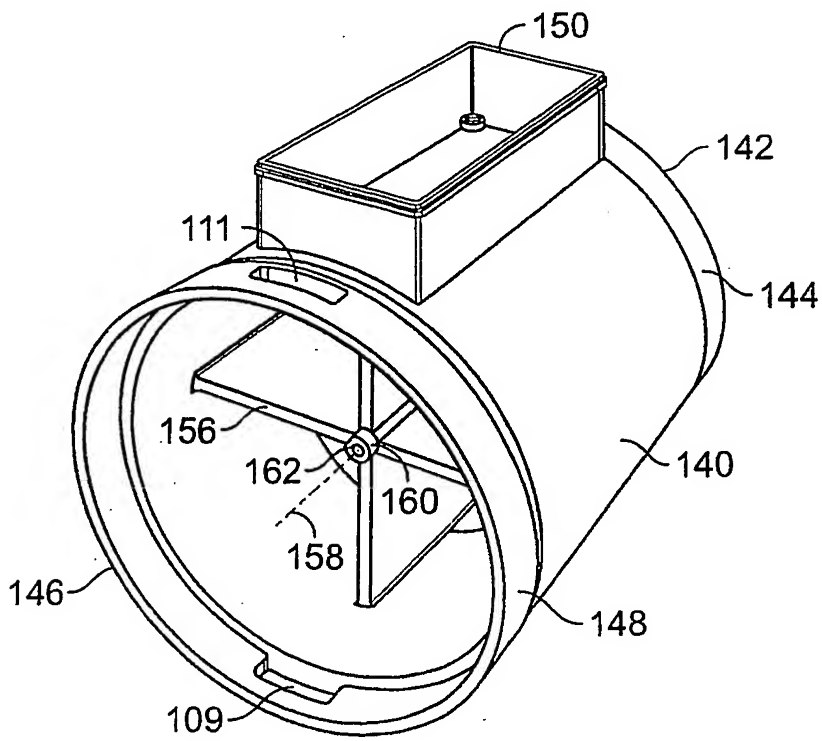


FIG. 6

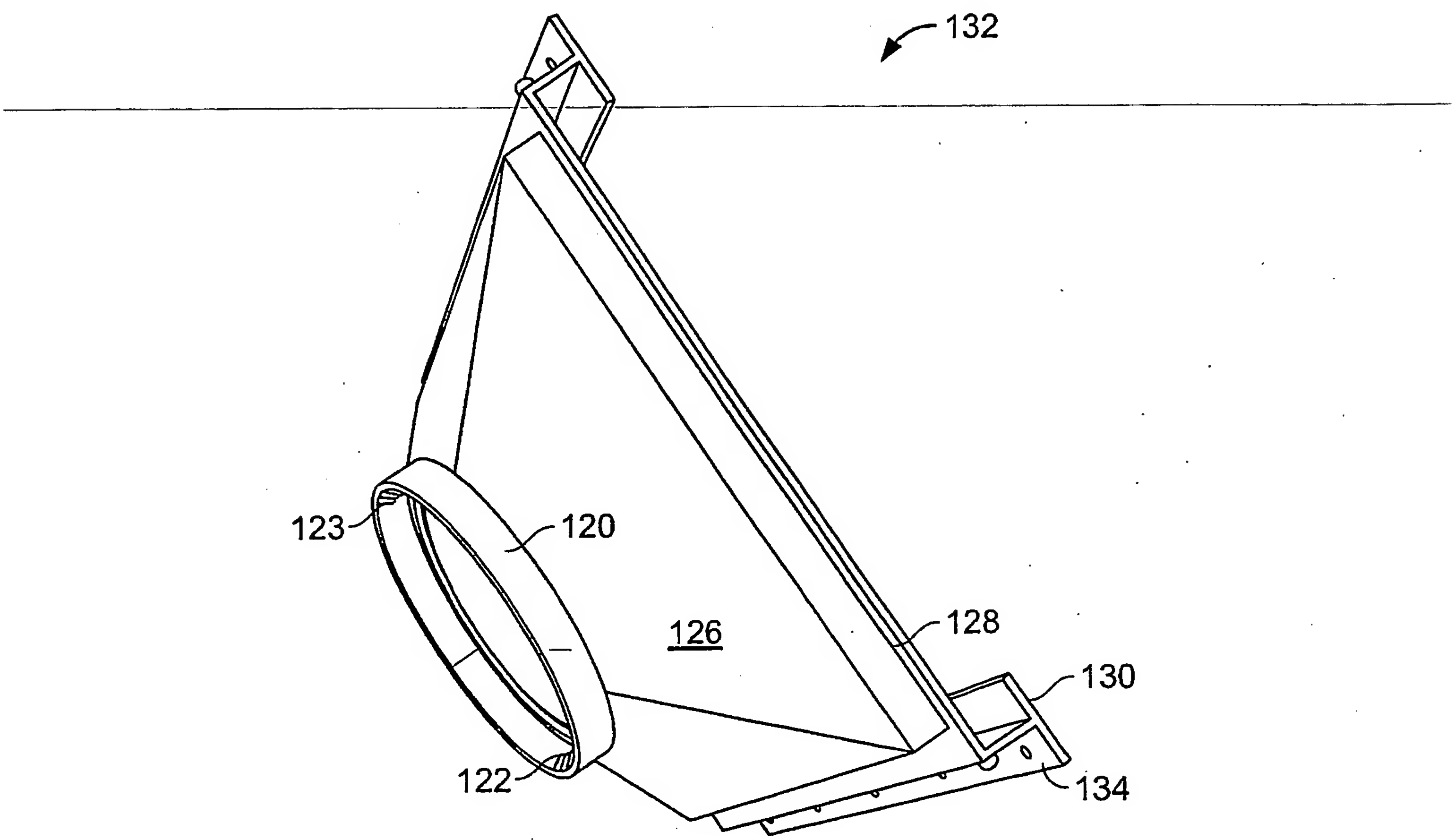


FIG. 7

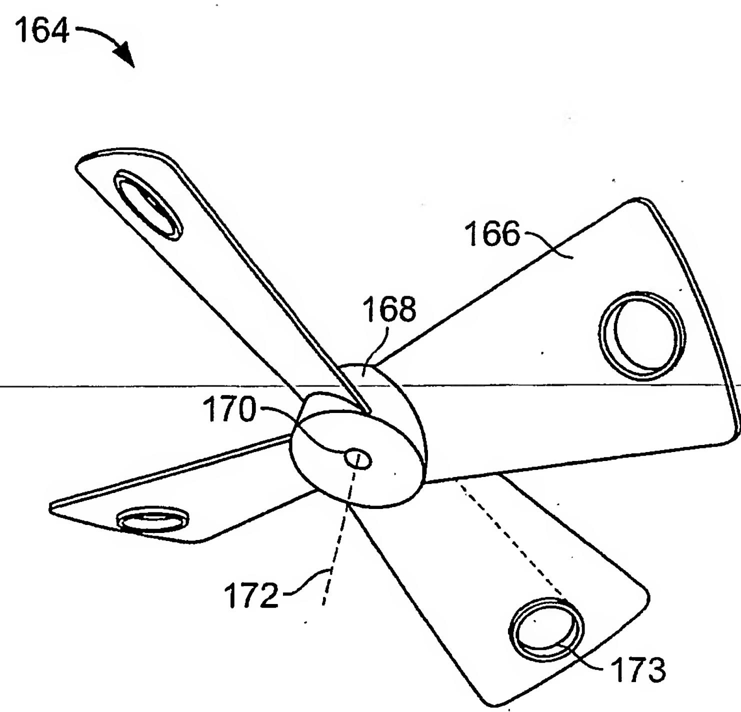


FIG. 8

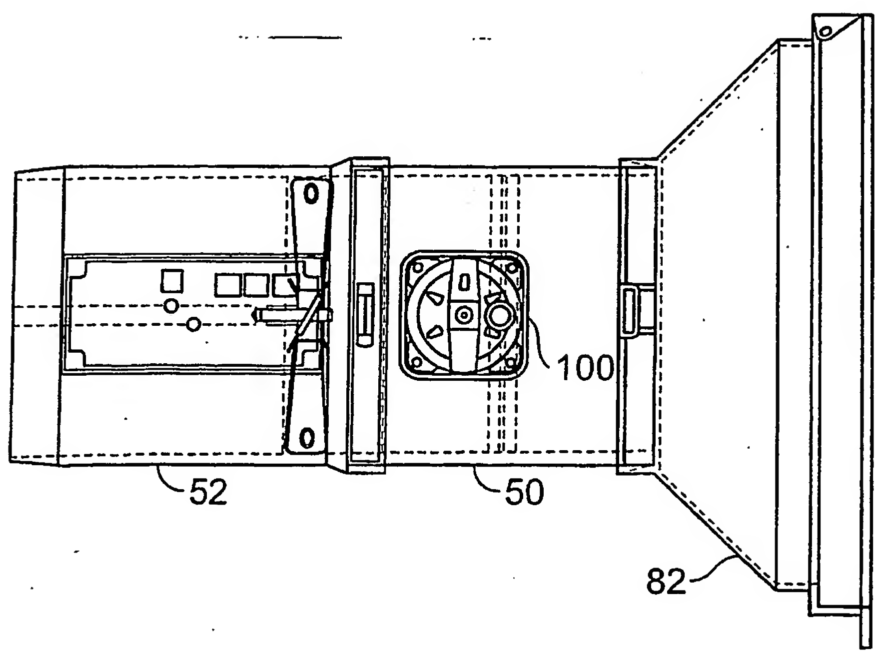


FIG. 9

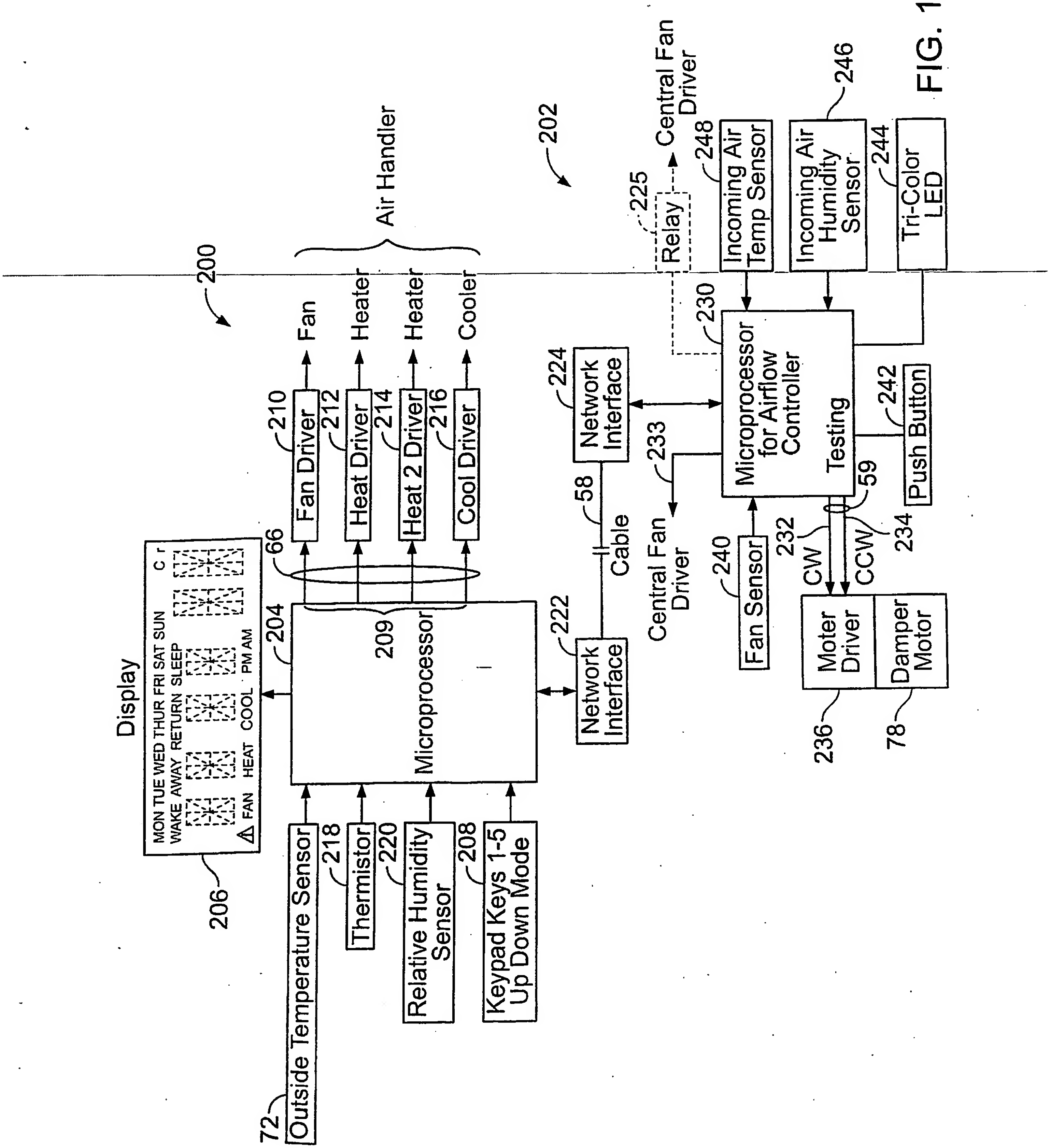

Display
MON TUE WED THUR FRI SAT SUN
WAKE AWAY RETURN SLEEP
FAN HEAT COOL PM AM
206
Outside Temperature Sensor
72
Thermistor
218
Relative Humidity Sensor
220
Keypad Keys 1-5 Up Down Mode
208
Microprocessor
204
209
66
Fan Driver
210
Heat Driver
212
Heat 2 Driver
214
Cool Driver
216
Fan
Heater
Heater
Cooler
Air Handler
200
202
Network Interface
222
Cable
58
Network Interface
224
Central Fan Driver
233
Relay
225
Central Fan Driver
Incoming Air Temp Sensor
248
Incoming Air Humidity Sensor
246
Tri-Color LED
244
Microprocessor for Airflow Controller
Testing
230
Push Button
242
Fan Sensor
240
59
CW
CCW
232
234
Moter Driver
236
Damper Motor
78

FIG. 10

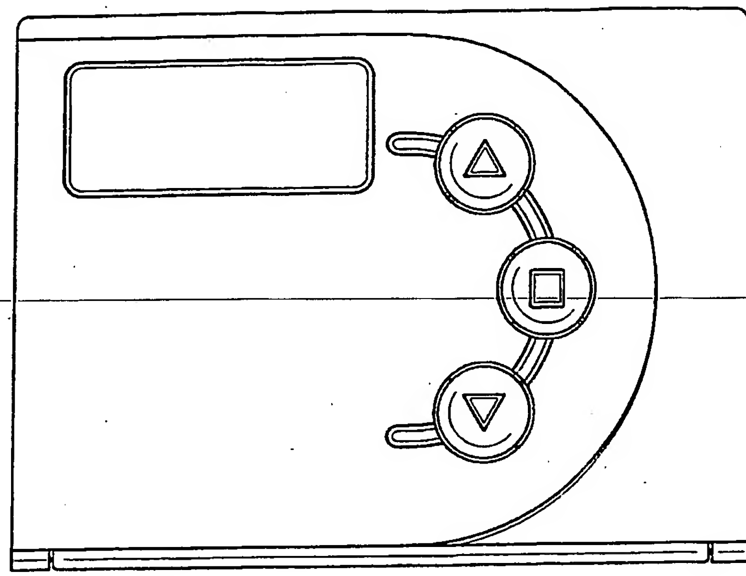


FIG. 11A

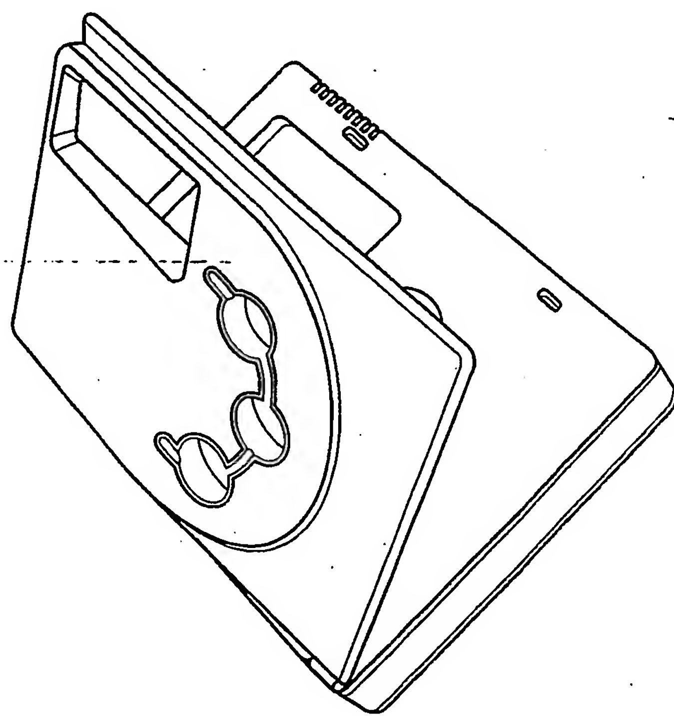


FIG. 11B

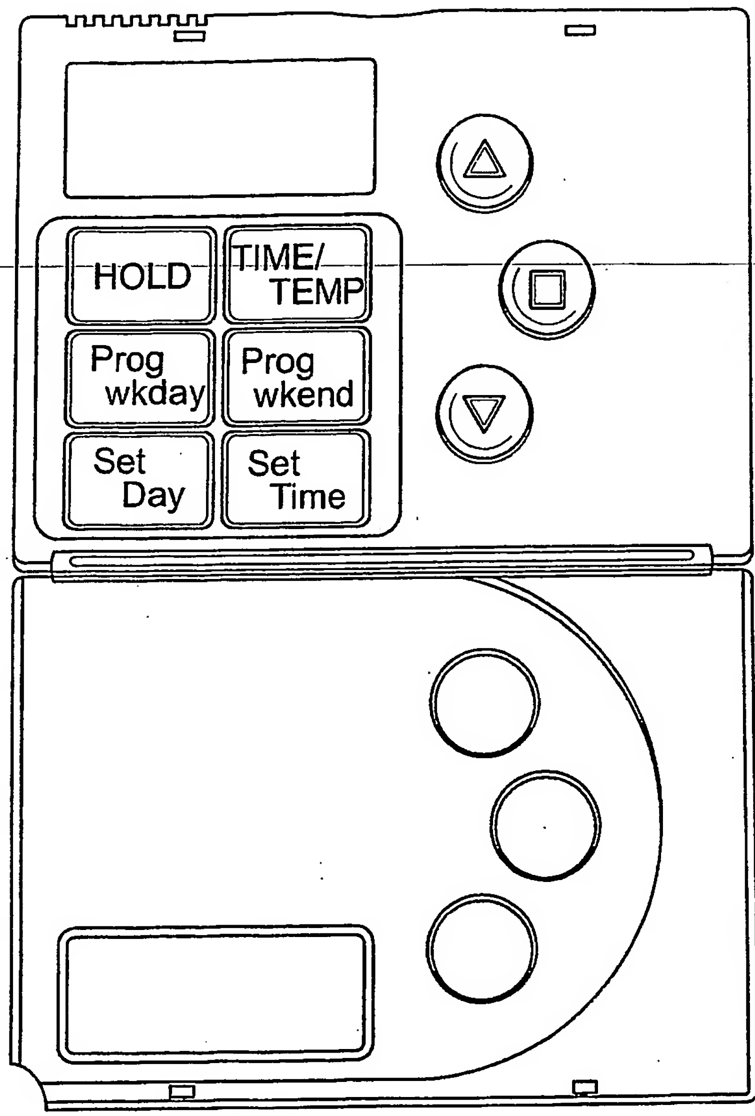


FIG. 11C

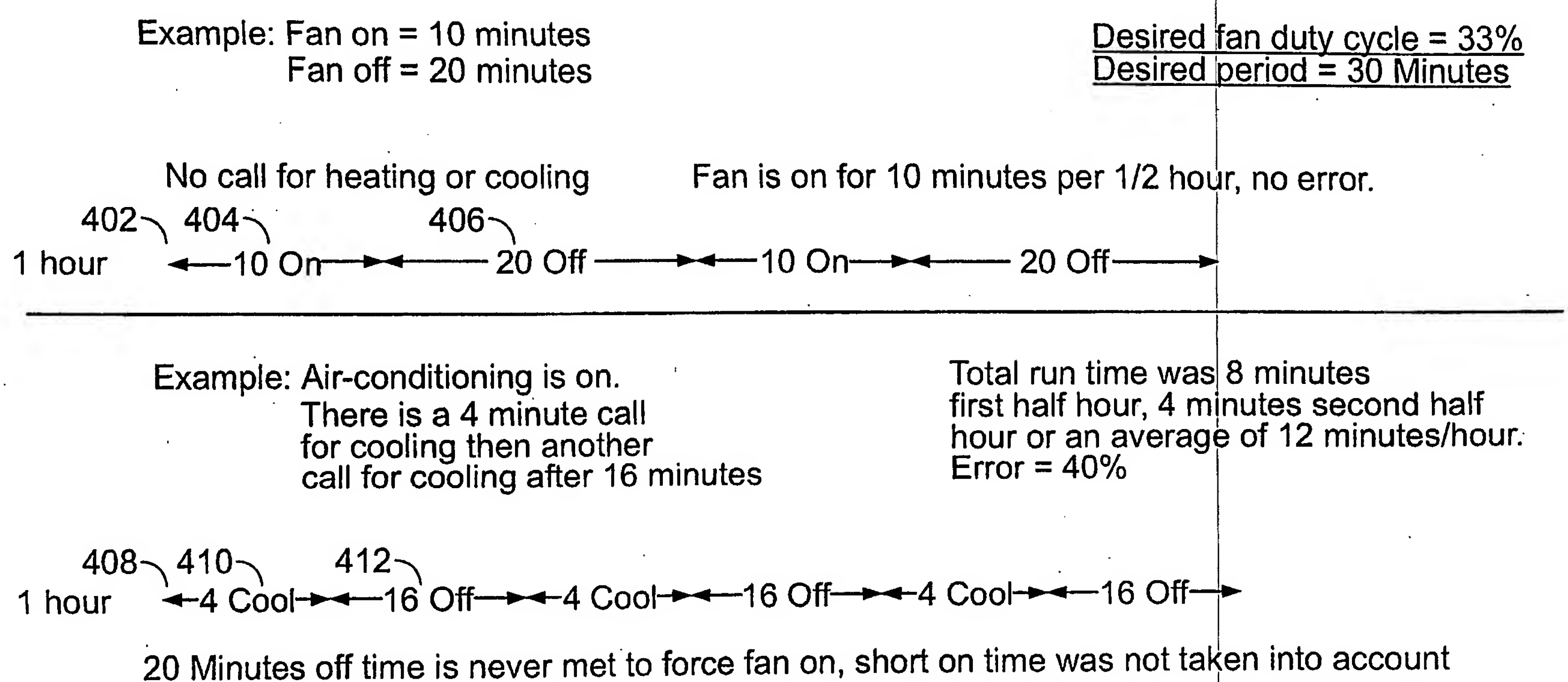

Example: Fan on = 10 minutes
Fan off = 20 minutes
Desired fan duty cycle = 33%
Desired period = 30 Minutes
No call for heating or cooling
Fan is on for 10 minutes per 1/2 hour, no error.
402
404
406
1 hour
10 On
20 Off
10 On
20 Off
Example: Air-conditioning is on.
There is a 4 minute call
for cooling then another
call for cooling after 16 minutes
Total run time was 8 minutes
first half hour, 4 minutes second half
hour or an average of 12 minutes/hour.
Error = 40%
408
410
412
1 hour
4 Cool
16 Off
4 Cool
16 Off
4 Cool
16 Off
20 Minutes off time is never met to force fan on, short on time was not taken into account

FIG. 12

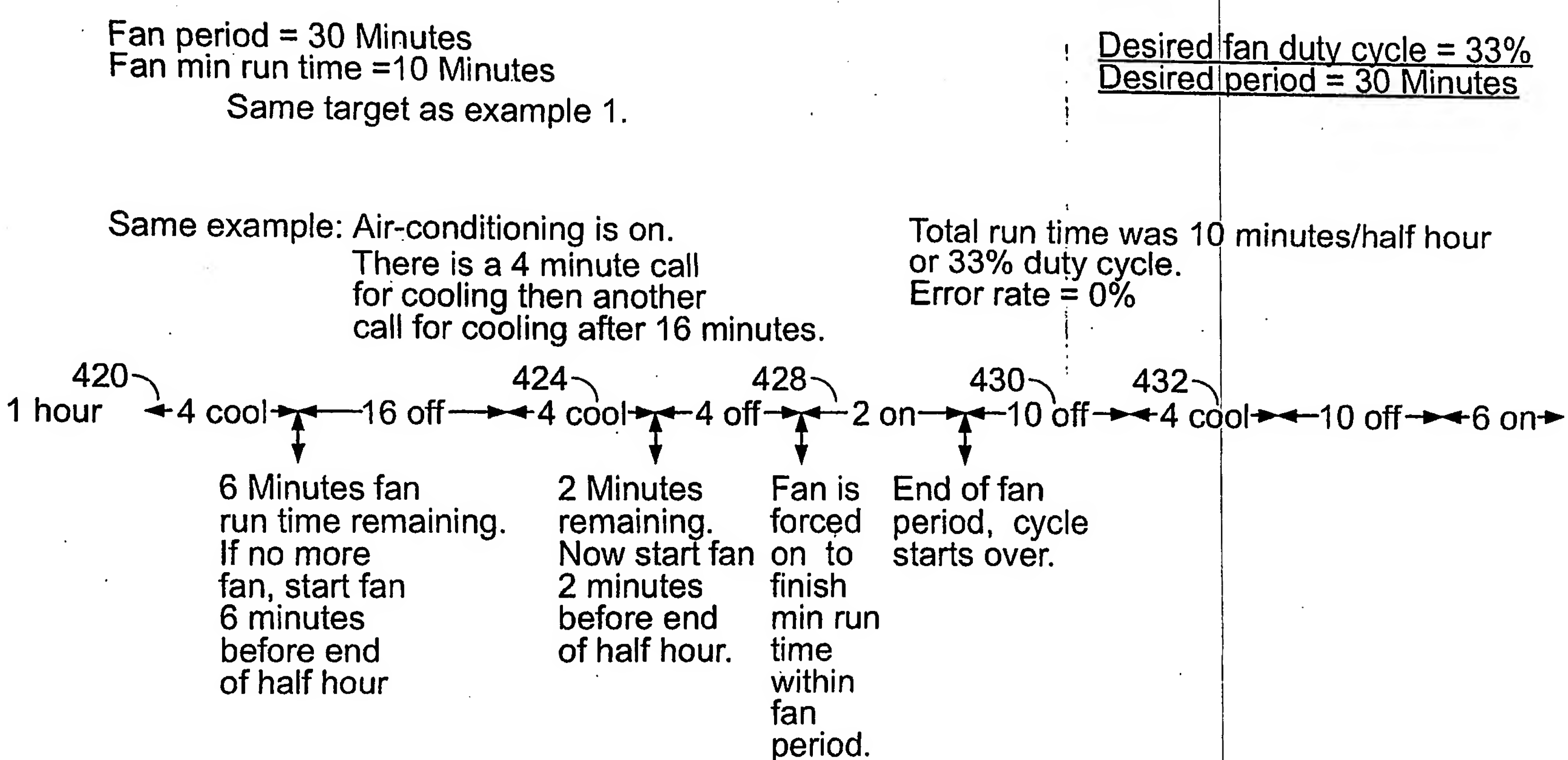

Fan period = 30 Minutes
Fan min run time =10 Minutes
Same target as example 1.
Desired fan duty cycle = 33%
Desired period = 30 Minutes
Same example: Air-conditioning is on.
There is a 4 minute call for cooling then another call for cooling after 16 minutes.
Total run time was 10 minutes/half hour or 33% duty cycle.
Error rate = 0%
420
424
428
430
432
1 hour
4 cool
16 off
4 cool
4 off
2 on
10 off
4 cool
10 off
6 on
6 Minutes fan run time remaining. If no more fan, start fan 6 minutes before end of half hour
2 Minutes remaining. Now start fan 2 minutes before end of half hour.
Fan is forced on to finish min run time within fan period.
End of fan period, cycle starts over.

FIG. 13

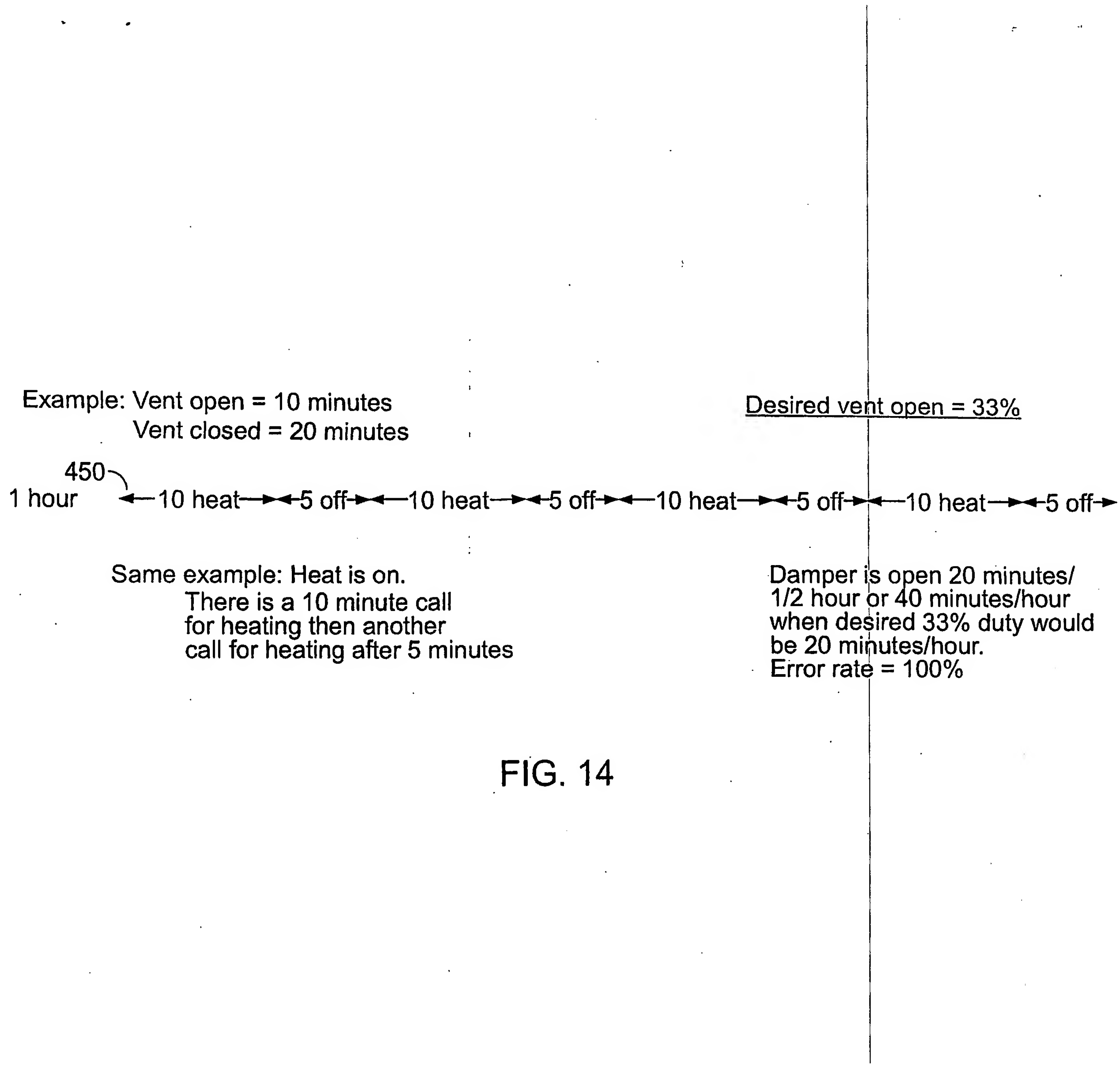

Example: Vent open = 10 minutes
Vent closed = 20 minutes
Desired vent open = 33%
450
1 hour
10 heat
5 off
10 heat
5 off
10 heat
5 off
10 heat
5 off
Same example: Heat is on.
There is a 10 minute call
for heating then another
call for heating after 5 minutes
Damper is open 20 minutes/
1/2 hour or 40 minutes/hour
when desired 33% duty would
be 20 minutes/hour.
Error rate = 100%

FIG. 14

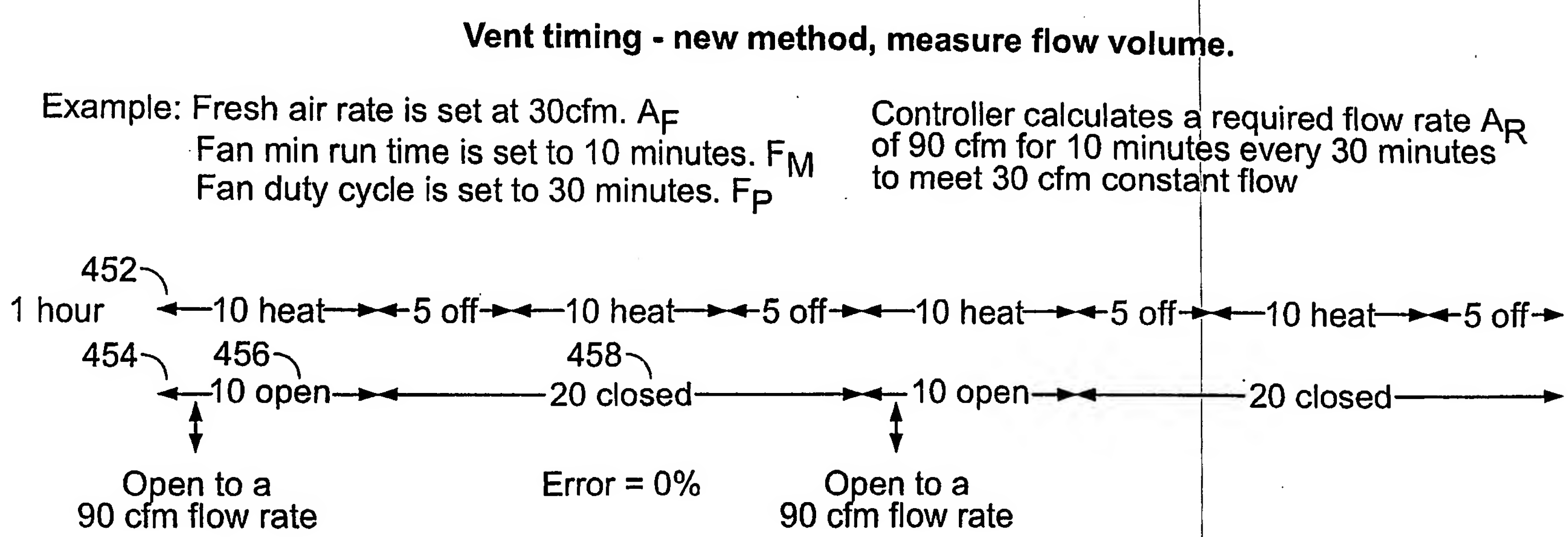

Vent timing - new method, measure flow volume.
Example: Fresh air rate is set at 30cfm. A F
Fan min run time is set to 10 minutes. F M
Fan duty cycle is set to 30 minutes. F P
Controller calculates a required flow rate A R
of 90 cfm for 10 minutes every 30 minutes
to meet 30 cfm constant flow
452
1 hour
10 heat
5 off
10 heat
5 off
10 heat
5 off
10 heat
5 off
454
456
10 open
458
20 closed
10 open
20 closed
Open to a
90 cfm flow rate
Error = 0%
Open to a
90 cfm flow rate

FIG. 15

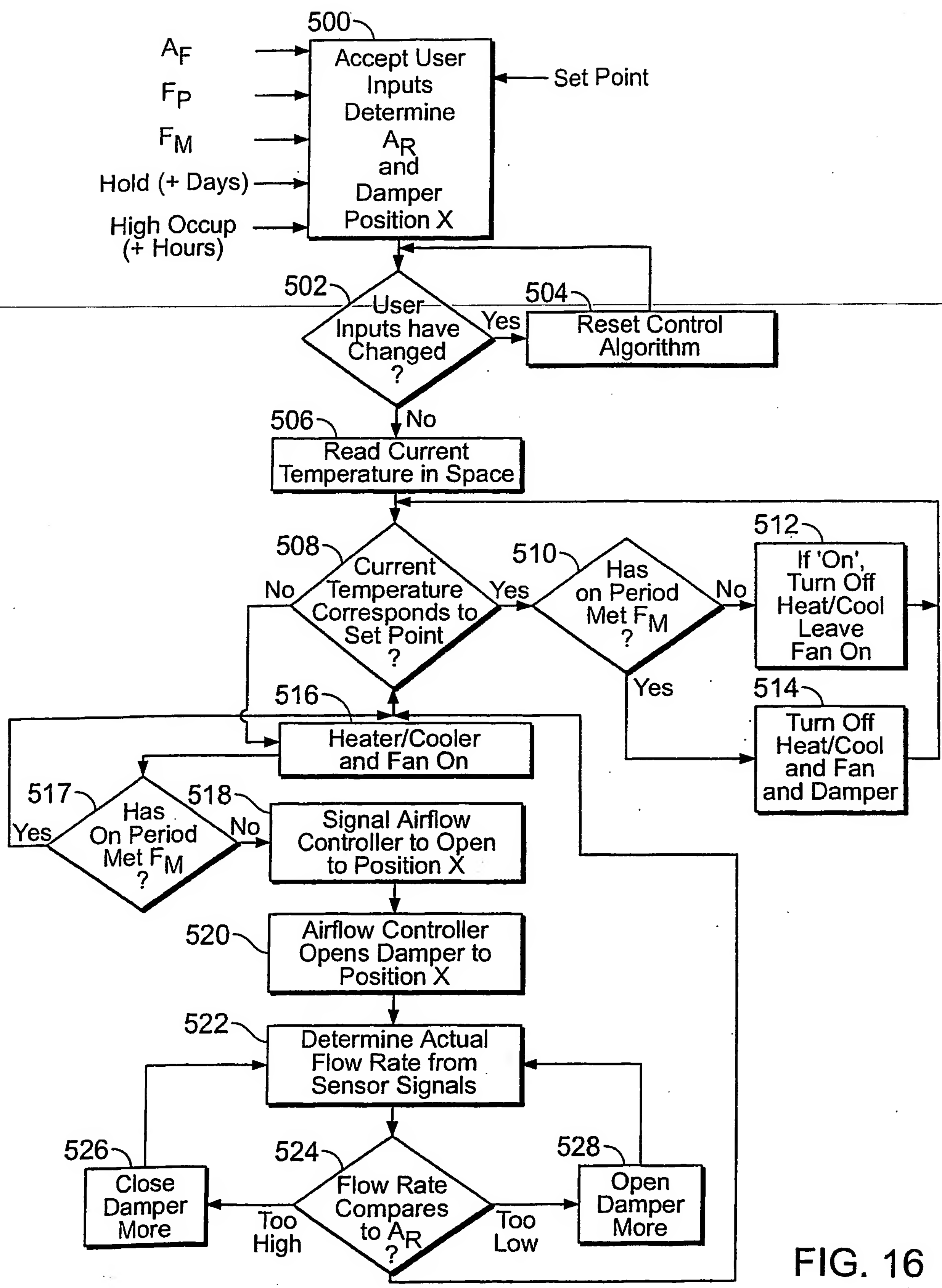

500
A_F
F_P
F_M
Hold (+ Days)
High Occup (+ Hours)
Accept User Inputs Determine A_R and Damper Position X
Set Point
502
User Inputs have Changed ?
Yes
504
Reset Control Algorithm
No
506
Read Current Temperature in Space
508
Current Temperature Corresponds to Set Point ?
No
Yes
510
Has on Period Met F_M ?
No
Yes
512
If 'On', Turn Off Heat/Cool Leave Fan On
514
Turn Off Heat/Cool and Fan and Damper
516
Heater/Cooler and Fan On
517
Has On Period Met F_M ?
Yes
No
518
Signal Airflow Controller to Open to Position X
520
Airflow Controller Opens Damper to Position X
522
Determine Actual Flow Rate from Sensor Signals
524
Flow Rate Compares to A_R ?
Too High
Too Low
526
Close Damper More
528
Open Damper More

FIG. 16